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A FORWARD LOOK

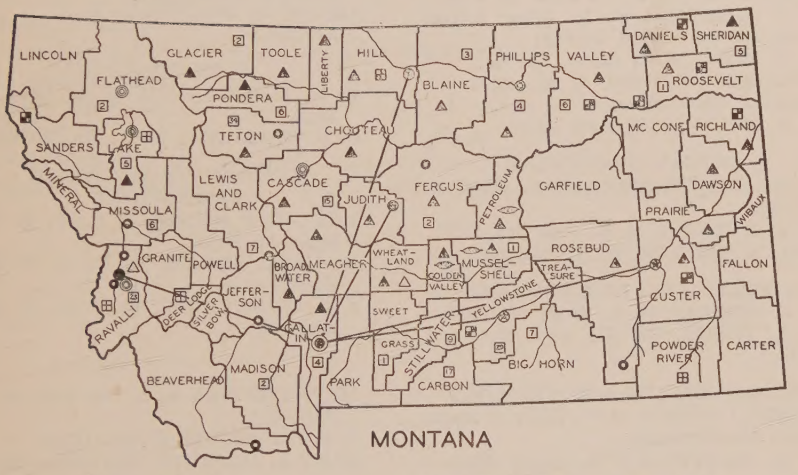
The Fortieth Annual Report

of the

Montana Agricultural Experiment Station

July 1, 1932 to June 30, 1933

F. B. Linfield, Director



- HOME STATION
- BRANCH STATIONS & U.S.D.A. COOPERATING
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AGRICULTURAL EXPERIMENT STATION
BOZEMAN, MONTANA

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Note—Organization as of November 30, 1933.
*On leave of absence.
**Cooperating with the United States Department of Agriculture.

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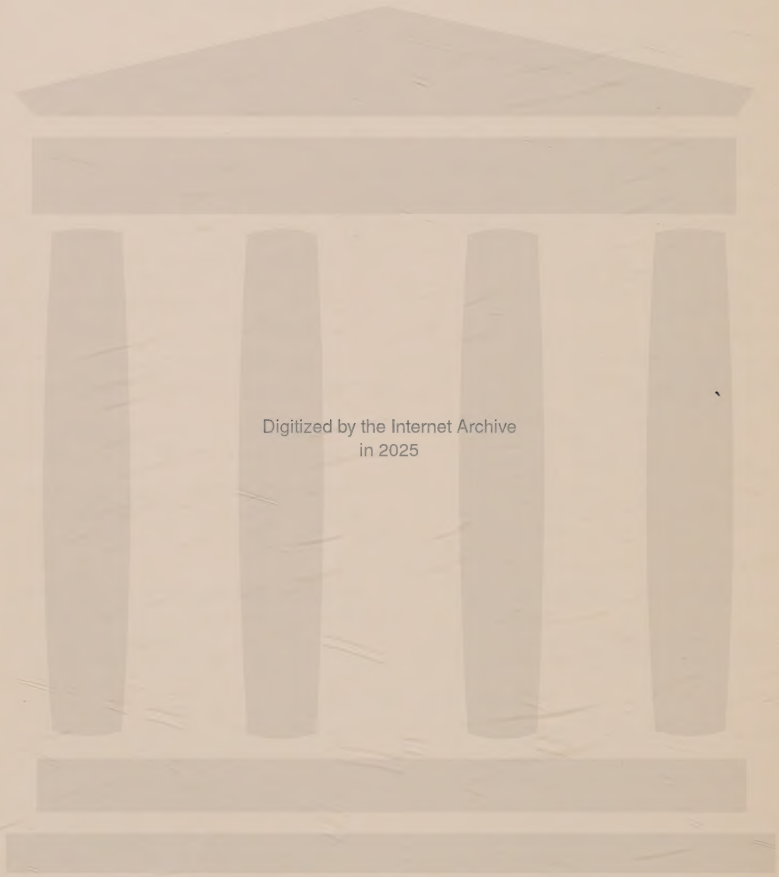

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A FORWARD LOOK

Agriculture the nation over is going through a period of stress and uncertainty. The situation is equally difficult for the Agricultural Experiment Stations of the country. The original task laid on them was to solve the agricultural production problems of a continent and give to the farmer the knowledge to control and guide nature's forces toward securing large and dependable crops. Associated with this was the building of a high grade live-stock industry. As knowledge has increased, agriculture has been spread over an increasing area of the country and now has reached the cropping limits. For many years the Experiment Stations have recognized that economic factors in their relation to agriculture must be considered but they could not foresee the sudden collapse of the past few years nor its tragic consequences. Montana was not well prepared to meet this emergency. First, much of the land of the state has been homesteaded in the past twenty-five years, and, as has been the experience in the settlement of other farm areas in the United States, many mistakes were made and people took up much land not suited for cropping. At the beginning of this period and for several years after, nothing was done toward making a systematic study of the soils of the state and of their adaptability or otherwise for certain crops.

Soon after the beginning of land settlement in Montana came the war in Europe into which the United States entered in 1917. From this followed a call for the farmers to produce to the limit, while at the same time many of the young men of the farms were called for army service. Two effects followed—first, a large increase in cropped areas; and second, increased use of mechanical power and larger farm machinery. About a year after the close of the war came a sudden and extreme drop in agricultural prices. Industry, however, continued to boom for ten years and reached a higher point of production than in any previous period in the nation's history. This was secured partly by urging installment buying, which was really borrowing on future income to satisfy a present consumptive desire. This meant also a continuous piling up of debt for which an end was sure soon to come. During this same time, moreover, the mechanical facilities of production increased while employment of labor relatively

decreased. This was repeating what had happened with agriculture during the previous thirty years.

The increased industrial development carried agricultural prices along a little above the low level of 1920, but gave no promise of improving or stabilizing the agricultural situation. The slump in industry which occurred in the fall of 1929 carried agricultural prices to the lowest relative level in the memory of our oldest farmers.

In addition to those factors which affected farmers generally, Montana had to reckon with two special problems. The first of these was extreme drought. Dry weather is normally to be expected in Montana, but we appear to be going through the trough of a long downward rainfall curve, with more frequent and more severe drought periods and seriously reduced crop yields. Another factor which we have had to contend with has been the decrease in crop yields which nearly always follows within a few years after land is first ploughed. Freshly broken virgin sod when moisture conditions are favorable generally gives excellent crops, as there seems to be an ample supply of available plant food, while the grass roots and surface vegetable matter keep the soil friable and in good tilth. In six to twelve years of continuous grain cropping, however, the readily available fertility seems to be rather completely used up and lower crop yields result. The conjunction of drought, the decreasing readily available plant food, and the extreme drop in agricultural prices proved disastrous to Montana agriculture in many parts of the state, particularly in the dry farming areas. Through the years, however, the Montana Agricultural Experiment Station has been studying the many agricultural problems of the state and accumulating facts that will make toward its stability and permanency, and these outlooks will be presented in the following pages.

A fundamental fact that must be given consideration is that Montana is, and will continue for a long time to be, largely a producer of raw materials which will find a market in the manufacturing centers in other parts of the country. This is true of our agricultural products but it is also true of the products from the forests and mines. Even though considerable manufacturing may be undertaken in the state, yet the bulk of our products will be shipped to outside markets. Coupled with this fact are others that must be considered in the picture. It would appear that the foreign market for a large portion of certain of our agricultural products is fast disappearing. There is also the probability of a stationary population in the United States

in the not distant future, while the sedentary life of most of the people will call for a lessened quantity of agricultural products. Again, all over the country the farmers are displacing horses with mechanical power, and this has released millions of acres for crops which will compete with crops used for other purposes. Furthermore, our climatic limitations compel largely the production of staple crops that are grown extensively over the nation and do not command special prices.

With this local, national, and international picture in mind, the farmers of Montana must seriously consider their agricultural production program. It is imperative, it seems to me, that we produce as far as possible those crops and live-stock products to which our soil and climatic conditions are especially adapted and those which can be grown most cheaply without loss of quality. This calls for a careful study of our farm possibilities and market prospects.

As we look into the future, we see that a very important task is to complete the survey of our soil resources, and from this work out a land classification, which will give the basis for determining the dependable and proper use of the lands in the various regions of the state. Accompanying this should be a survey of the grass and other cover on these soils which will be of particular value in estimating the safe carrying capacity for live stock and suggesting plans for improvement of the range.

Such a study of the lands of the state would broadly classify them into pasture, dry farming, and irrigated areas. The development of the range country seems to point toward a more intensive range live-stock industry, largely toward the cow-and-calf and the ewe-and-lamb as the live stock units. This calls for the development of a readily available water supply all over the range country, for intelligent control of the range pastures, and for units of land large enough for each stockman or sheep owner to support adequately a herd of a size to give a satisfactory income. The amount of land will vary with the type of the soil and the different regions of the state. There must be better care of the young stock and this will demand better ranch equipment and good ranch organization. To put this new type of industry on a safe basis will require an ample supply and some reserves of winter forage to maintain the young stock and also to provide against the years with low feed supply and the hard winters.

Under normal business conditions the products of Montana ranges find a ready market in the United States. This country does not produce sufficient wool to supply the nation's needs. Some improvement in quality in the finer grades, which is easily possible, would meet all national requirements for high-grade fine wool. Large numbers of cattle, sheep, and lambs are always in demand by the feeders of the Corn Belt and there is always a demand for the live stock fattened within the state.

In the dry-land areas, only the better lands can be cropped to advantage under present economic conditions. Low costs in production of grain crops are necessary and this is only possible with large farms and with large machinery. Wheat will continue to be the principal crop on such farms, but with cheap lands and a premium on high protein wheats, Montana should continue to grow this crop, as there is seldom a surplus of this high quality wheat. In the mountain areas and on the foothill farms, sheep and beef cattle may be combined with grain growing on the dry lands where a variety of roughage may be produced, such as corn, grain hay, sweet clover, alfalfa, etc. Ample feed reserves, however, should always be maintained.

Irrigation farming has made considerable progress in Montana and there is yet much room for expansion, but this is tied up with water conservation. The flood waters which flow out of the country in the spring frequently do more harm than good to the country. Wherever possible all such run-off should be held back in reservoirs. Much of this can be used later to irrigate crops or to develop power. This will spread the run-off through the year and equalize the flow of the lower streams.

The irrigated lands of the state have to bear the original cost of bringing this water to the land and then each year pay for maintaining the irrigation works and for spreading the water over the land to irrigate the crops. The irrigation enterprise does more than this, it creates business and maintains the villages, towns, and cities, which live on the trade which the irrigated districts create. This important fact is being recognized in some states and so the development of an irrigation enterprise becomes a community expense and not that of the farmers only.

The irrigated farm community bears about the same relation to the town or city as does a large manufacturing enterprise in the city, with this difference, that the manufacturer distributes only what is

left after interest, dividends, and management have been paid, while the farmer gets only what is left after the distributive agencies take their toll, the amount of which these agencies largely determine.

Irrigation on the farm makes possible more intensive and more dependable crops and the dependability of this enterprise is also reflected in the greater stability of the whole community—the town and city as well as the farms. It also affords opportunity for greater diversity in agricultural production, both with crops and with live stock. When good farming practices are followed the farmers can usually count on large crop yields on the irrigated farm while it also provides good pasture the summer through and an abundance of winter feed, the basis for the intensive phases of the live-stock industry.

In the irrigated valleys and many of the foothill areas the climatic conditions of the state also make possible the production of many crops which will hold their own in the competitive markets of the country. To obtain the largest returns from our agriculture, we must increase the returns on those products in which we can excel in yield and quality. Illustrations of such crops are sugar beets which, because of the possible high yields and high sugar content, are a very important crop in the lower irrigated area; beans also do very well in these lower valleys; alfalfa seed, especially such hardy varieties as Grimm and Ladak, does well in this northern area and finds a ready market. In the higher valleys peas for seed and for canning yield well and make a dependable crop. Potatoes, because of their excellent quality, find a market in some seasons as far east as Chicago and under average economic conditions many carloads of seed potatoes are sold to the states south of us. I believe we will yet find other lines in which a quality product will prove of decided advantage to the Montana farmer.

In the production of live stock and live-stock products, the same logic will apply. The growing of purebred live stock of high quality is increasing in Montana. Experiences are accumulating which show that animals equal to the best found in the United States may be bred, grown out, and fitted in Montana. This will apply to horses, beef and dairy cattle, to sheep and to other animals. We have yet something to learn, however, in the art of feeding and management of our live stock.

The cool climate of the mountain valleys, the all-summer pastures of the irrigated areas, the quality of the grain and roughage, and the abundance and fine quality of water supply make possible abundant production of butter and cheese of superior quality. I know of no place in the nation where the possibilities are any better. We have yet something to learn on the care of milk, on the methods of manufacturing, and on the care and marketing of the product.

Montana may also excel in the production of bacon hogs and in growing and finishing turkeys and other poultry. In all of the foregoing endeavors, we need yet something of cooperation and coordination in our production and marketing, some definite planning, and some careful study of the problems growing out of these endeavors to work together. The way is clear in practically all these fields to continue production, because, except for wheat, Montana products under average economic conditions find no surplus on the market.

The large field of work for the Experiment Station has been and is with the production and distribution problems. We have not been neglectful, however, in the study of the diseases and pests that may impair or destroy the farmer's crops and live stock. The station has gone far in working out cures for the diseases and methods of control for the insect pests which the farmer may apply, if he will but ask for the information. Our knowledge in these directions is by no means complete, but substantial progress has been made. In some directions facts are being accumulated which will enable us to anticipate damaging increases in insects, and thus plan definitely for their control. With continued study it is hoped that outbreaks may be still further anticipated and serious outbreaks prevented.

The sum total of these endeavors should find expression in better living on the farm and better satisfaction in farm life. The farmer in the United States has been fortunate in that, if the farm life did not appeal to him, either he or his children could move to some other occupation which was more congenial or more profitable. Thus to a large extent he has been a farmer from choice.

In some cases, it is true, the farm was but a stopping place or a temporary occupation where a man could get a start and accumulate reserves to be transferred by him to a more congenial occupation. There are indications, however, growing out of the present economic situation and the factors leading up to it, that it will not be so easy in the future to move to the better place. It behooves the farmer,

therefore, to study how to make the most out of his present place and add to the farm as a source of income those things which will make it the most desirable place to live. This is easily possible on the irrigated farms and in the foothill areas. The farm is the source of all food staples and on the farm they may have that preparation for the table that will make them not alone nourishing but most palatable. The staples, however, should be supplemented by other things which nearly every farm could produce, namely all hardy vegetables and many hardy fruits. Some of these may be canned for winter use but many others could be stored, if a suitable cellar were provided. Many may provide for their table more elaborately but none should be able to live better than the farmer.

A good supply of provisions should be supplemented by the home beautiful. It may not be large and a little paint or other covering may in many instances improve it both inside and out. A small lawn, trees, and shrubs properly planted around the house add wonderfully to the attractiveness of the farm home. Add to this annual and perennial flowers and no home need be more attractive. Our studies show that there is scarcely a farming area in the state where certain trees and shrubs will not grow and in most places tree and small fruits are possible. A supply of water will extend the variety and the dependability of the garden, the fruit crop, and the trees, shrubs, and flowers around the house. In some places a well, a windmill, and a small tank will furnish the water, while in others a dam across some coulee, fenced off from the stock, may supply the water needed.

The thought in all this is that to a large extent agricultural pioneering in Montana is drawing to its close. Speculative increases in land values can not be counted on any longer. The chances for a career in other directions are lessening and so we must plan our farm and its home and our farm operations on a long-time and a more permanent basis. For most of the farmers, the future must be on the farm and dug out of it. If this does not lead to the spectacular in wealth or position it at least should give security, satisfaction, and comfort, and the best place in the world for the boy or girl to grow up and make life's start is on the farm, if we will it so.

SOME ECONOMIC PROBLEMS OF THE FARMS AND RANCHES

The economic problems before the agricultural people of the United States are of a dual nature. They have much of an emergency aspect, in fact, day-to-day routine is very largely taken up with emergency problems. Long-time programs, however, are being worked out on a larger scale than ever before. Practically the emergency and the long-time problems become definitely interwoven since each emergency program has its effect upon long-time developments. Moreover, the emergency program should be carried out in the light of such permanent plans as can at present be envisioned.

The decline of the foreign market for agricultural products has made it necessary to adopt a series of control programs designed to adapt the agricultural production of the nation to the effective demand and thereby eliminate the waste which comes about through an excess of food stuffs and other raw materials. The agricultural adjustment programs call for widespread curtailment of the number of cropped acres, these acres to be reduced in the same proportion for all farms producing the same commodity. This brings up a specific set of problems in farm management as the production factors of all farms are temporarily disorganized. To obtain the full benefit from controlled production it is necessary that each farmer adjust his productive acres so that all of them may be used to the maximum advantage. On the efficiently organized and well-equipped farms, sufficient agricultural products may be obtained to supply the nation's needs, yet with a decided reduction in human labor. Hence, full-time use of the farmer's labor is not the immediate problem but rather the reorganization of the farm enterprise on a more efficient basis.

The major phase of this problem is a change in the use of the farm lands. The farmer may find it advisable to reduce the kind and amount of crops grown by following a more extensive type of agriculture than he has practiced in the past, or the acreage may be reduced and a more intensive farm practice followed. Some information has been gathered on the principles involved in these readjustments but much more is necessary if loss and confusion are to be avoided.

The problem of readjustment, however, extends beyond the individual farmer; it concerns all farmers collectively. The propaganda for dry-land farming, followed by the war urge to produce to the limit,

together with the high prices and the increased use of mechanical power on the farm, brought a greatly increased acreage of the country under the plough. This extraordinary use of land added greatly to the level of agricultural production in the country, which after the war forced prices down to an unprofitable level. Moreover, much of the land thus turned to cropping proved unsuitable for this purpose. In the humid regions the rolling lands then broken up tended to be eroded by water, while in the western dry regions wind erosion has destroyed large areas, and in other places only low yields were possible, which could be profitable only under continued high grain prices. The people who control these lands are now confronted with a dual problem: first, the land is not suited to the temporary use to which it was put; and second, the land has deteriorated from its original usefulness. Moreover, these conditions lessen land values, reduce the desirability of the area for any type of farming, and call for some efforts toward preventing further destruction of the lands.

These conditions have resulted in waste of land resources, in economic disaster to the farmers and the agricultural communities, and in a national demand for some definite program of land use planning. The purpose of this planning is also to correct many of the mistakes of "wild cat" land settlement, which resulted in so much loss and disaster. To prevent a repetition of such disaster we must determine as accurately as possible, in so far as our present knowledge will permit, the use for which the land of the nation is best fitted.

Such a program must necessarily be based, first, upon the relative productivity of the soil; next, on the knowledge necessary to convert this productivity into economic terms, so that the information may be used by the people owning or living on the land. The soil studies that have been carried on by the Experiment Station for many years give a basis for determining productivity, but unfortunately only about a third of the state has yet been covered by these surveys. The Agricultural Economics Department adds to these surveys studies on actual crop production and costs of farm operations, to determine the possible economic returns. The studies by these departments first broadly classify the soils of the state into farming and grazing areas, and these into subclasses according to the productivity of the land.

Water conservation in Montana, where so many people live under semi-arid conditions, is a major problem in crop production and in satisfactory community life. The most obvious task is to find what water supplies may be made available for irrigation; first, to supplement the water of the present irrigation projects; second to develop new major irrigation enterprises; third, to establish minor irrigation projects wherever possible; and, fourth, to store flood waters and build diversion dams over the range country, to provide stock water and a supply for irrigating limited areas.

Each of these proposals for enlargement of the irrigated area of the state should be carefully studied in the field to determine costs and benefits, while surveys should be made of the soils to which it is proposed to apply the water, to determine the crops that are possible. This will call for careful study by the agronomist, the engineer, and the agricultural economist.

The irrigation projects in Montana are widely scattered over the state and include a great variety of soil and climatic conditions. Each presents some special problems for study. Some are only partially developed, others fail to produce satisfactory crops because of faulty agricultural practices, or are not growing the crops best adapted to the region. These and other problems require careful study and analysis in the light of past experiences, and the accumulation of further facts. This study should be thorough and made as soon as possible.

Three-fourths of the area of Montana, if used agriculturally, must be used to provide feed for live stock. The future of this industry will be influenced by national land policies and live-stock programs. The coming of the settler changed radically the old live-stock industry in Montana and a national land use program will call for further adjustment. If the change is toward some definite control, whether individual or communal, this will make possible some development of the range country and the restoration and maintenance of the grass cover. Such control will permit development of readily available water supplies and the production of winter feed adjacent to the ranch. It will then also be possible to work out more desirable organizations for both cattle and sheep ranches, which will make for stability in the live-stock industry. The present ranch organizations have received as yet but limited study and much more should be given especially as any changes bring new problems. The complete picture calls for further definite information in regard to the lands

of the state. The first of these should show the present use of the lands and the actual location of the farms. This information is being obtained from the wheat control associations, which give records of the use of land in 1933, together with the acreages in crop and in pasture, and the production for the previous three to five years. To these figures will be added the records of the cattle control associations as soon as they are available.

Information is also being collected on the ownership of the various farms and ranches. For certain kinds of land use, control of definite areas is necessary. For instance, a grazing area should preferably be in a solid block of sufficient size to support a satisfactory number of live stock. Under intelligent control such a grazing area is a more efficient meat producer than the open range and gives more stability to the ranch organization. To designate lands for these or other uses, it is very important to have a complete record of land ownership.

The tax history is another fact necessary to intelligent planning of land use in any area. A major problem concerning not only agricultural people but the whole community is the large percentage of land which is subject to a tax deed and, therefore, about to revert to public ownership. A study of the taxation situation may also reveal the ability of the land to support the farming community. First, it must supply the necessities of living to the family, and next, provide those things which can best be obtained through cooperation of the people living within the specified civil unit, including schools, and other public services, which are essential in the present stage of our civilization.

To what extent these public services are efficient is also a fact to be ascertained. This may have a relationship to the best distribution of the population and may suggest some changes that will better serve all the people and at less cost.

A FUTURE LAND USE PROGRAM FOR MONTANA

When an attempt is made to predict the future of the crop production possibilities in Montana, to outline a program of crop production for the state which will fit into the new economic picture, one unconsciously turns to the experiences of the past, for it is out of the successes and failures that are behind that the more permanent structures of the future are built.

In reviewing the "trial-and-error" process of developing Montana's agriculture that has largely prevailed in the past, there is revealed a situation for which no one in particular was responsible, nevertheless a situation that should not be overlooked in making plans for a more permanent and profitable program of crop production in the future. As a guide to permanent agricultural development, Montana's experiences during the homestead era may be regarded as rather misleading. The decade from 1907 to 1916, covering the time when the greatest number of original homestead entries were made in this state, was clearly above normal so far as rainfall and, hence, crop production were concerned.* This ten-year period showed three bumper crops, two very good crops, two good crops, two medium crops, and one poor crop. Not a single failure was recorded during the ten years, whereas through the thirty-three years since 1900 the average of the ten-year periods has produced one failure and two poor crops. With the impetus of a series of favorable seasons, combined with good prices for farm products, it is not at all surprising that thousands of acres of Montana's good grazing land yielded to the plow, only to demonstrate to the operator, with the return of less favorable seasons and lower prices, that much of this land was distinctly submarginal and should never have been disturbed. Perhaps the policies of the past with regard to the settlement and use of land were the best for conditions as they then prevailed, certainly they were policies which were inevitable in a pioneer country. However, the pioneering stage is a thing of the past, and there is a distinct need for a land policy based on careful studies of present as well as future demand for the various products of the soil. Past mistakes may be corrected in part, and future mistakes reduced to a minimum, by the adoption of a program of land utilization which will insure that the various kinds of land will be used for the purposes for which they are best suited. These and like experiences from the land settlement of these western states, which were intensified by the business depressions, showed the great necessity for a systematic and thorough study of the land resources of the country and of an intelligent land use program based on facts. National attention was focused on this need by the Conference on Land Utilization held in Chicago in November, 1931.

This conference stressed the fact that the economic use of agricultural land is directly affected by the topography, climate, texture

*Montana Extension Service Bulletin 136, page 6. 1933.

and chemical properties, biological defects, and locations, since these are major factors in determining the value of land for production and taxation purposes. The conference recommended "that a national inventory be made of our land resources, that soils be classified on the basis of their agricultural value, and that our land taxation system and practices be readjusted accordingly." The same conference stated that "an essential basis in land utilization is adequate physical data in the form of soil surveys, topographical surveys, weather records, etc."

Information secured through soil surveys.—The soil surveys collect detailed information on all these soil characteristics which indicate productive capacity. These characteristics include, among others, color, texture, structure, depth, topography, and soil reaction. Generally speaking, black soils indicate available fertility resulting from a large amount of decayed vegetable matter. The presence of an abundance of decayed vegetable matter suggests that rainfall has been sufficient to produce a luxuriant growth of vegetation. Texture, which refers to size of particles, has a marked influence on the moisture-holding capacity and also is related to the supply of available fertility and the physical condition of the soil. The depths of the soil and subsoil are important in their relation to the storage of soil moisture and root growth of crops to be grown on the land.

In addition to information on soil characteristics, the soil surveyors collect data on climate, including rainfall, temperature, frost, evaporation, and wind velocity. Record is also made of the elevation, native vegetation, adapted crops and production methods, streams and water supply, public service, including schools, roads, etc. All this information is prepared in the form of a written report on each county, together with a map showing the extent and location of each soil type.

Soil surveys in Montana.—So far not over 40 per cent of the lands of the state have been surveyed. The soil reconnoissance has covered about 35,626,240 acres and the detailed survey of the irrigable areas about 2,199,280 acres. The estimated area yet to survey is 38,000,000 acres for the soil reconnoissance and about 3,000,000 acres of irrigable lands. On the basis of the funds available in the past it will take twelve to fifteen years to complete the soil reconnoissance of the state.

Topography and climate in relation to land use.—The northern Great Plains area extends into Montana and comprises nearly half of the state. The remainder, or mountain area, extends across the Rocky Mountains with their adjoining foothills and valleys. Topographically, therefore, Montana lands may be roughly divided into three major areas: (1) the Great Plains, (2) the foothills of the Rocky Mountains, and (3) the intermountain valleys. The elevation of the farming areas in plains and valleys ranges from 2,000 to 6,000 feet above sea level. The climate west of the Rocky Mountains is influenced by the winds of the Pacific Ocean, east of the divide by the winds of the chinook belt, and farther east by the storms out of the northwest. These physical and meteorological conditions give to Montana a great variety of climate in the different regions of the state; consequently there is a greater variety of crops and cropping conditions than the northern location of the state would indicate.

Because of the variation in elevation, in temperature, and in precipitation in each of these major areas, it is not a simple matter to formulate a state-wide program of land use. However, in planning for the future the Montana Agricultural Experiment Station stands prepared to submit the results of forty years of fairly intensive study of some of the state's most important agricultural problems and to assist in making plans for reducing the risks connected with agricultural production under our various types of farming and ranching. The findings of the soil survey, the results of crop and soil investigations, research to determine the best systems of feeding, breeding, and management of live stock, and economic studies of farm and ranch operations, now point the way to agricultural production on a "safe and sane" or planned basis.

Moisture a limiting factor in land use.—Every one who is familiar with agriculture in the northern Great Plains knows that moisture is quite generally a limiting factor in agricultural production. A comparatively low annual precipitation, even though distributed mainly during that part of the year when it is of greatest benefit to growing plants, is subject to a fairly high rate of evaporation. A permanent basis for Montana's agriculture therefore involves water conservation by dams and reservoirs over the range country, by large storage works for the irrigated lands, and by efficient methods of moisture conservation in the soil through proper cultivation and cropping methods.

CLASSIFYING MONTANA'S AGRICULTURAL LANDS

Based on the foregoing type of facts as obtained by the soil survey parties, supplemented by studies on crop and soil relationships, animal husbandry research, and economic studies, it is possible to designate the general location and extent of land suitable for the production of grain and forage and also to map the areas which should be permanently set aside for grazing. The lands of the state may thus be broadly grouped into three classes, namely, (1) grazing lands, (2) non-irrigated (dry farm) lands, and (3) irrigable farm lands.

The grazing land may be again divided into five or more grades, according to the quality and the carrying capacity for live stock. It is estimated that 70 per cent of the area of the state, or about 66,500,000 acres, will find its best use as grazing land from the agricultural standpoint. Some 20,000,000 acres of this land, however, is in forests.

The non-irrigated or dry-farm lands of the state may also be separated into four or more grades, based on the average yield of spring wheat on summer fallow through a number of years. These yields are 21 bushels or over for the first grade, down to 8 bushels for the lowest grade. These pictures of average land productivity give a basis for measuring land values and use.

The irrigable farm lands could be graded on the same basis as the dry-farming land, but an abundant water supply brings up many other considerations which, again, vary with the climatic differences in the various parts of the state. Perhaps alfalfa, which is grown all over the state as an irrigated crop, provides the best measure of soil differences. A yearly crop of 3½ tons per acre or over would be classed as indicative of first grade land, while from 1¼ down to 1 ton would be fourth grade land. However, under irrigation and proper fertilization it is possible to build up the fertility of irrigated soil to a higher class. With irrigation the climatic factor is very important in determining the efficient use of such lands. The irrigated area of the state is not limited by lack of suitable land, but by a sufficient water supply and the cost of getting this water to the land.

All of the foregoing classifications are now possible on the areas of the state covered by the soil surveys but can not be applied so definitely on the remaining lands.

FARMING POSSIBILITIES AND FUTURE TRENDS IN CROP PRODUCTION

Dry-land farming.—The lands in Montana adapted to "dry-farming" are included largely in what is properly referred to as the northern Great Plains. Dry farming is a business which requires considerable capital and much technical skill. Capital is essential to equip an area sufficiently large to return a satisfactory income as well as to carry the operator and his family through the "dry years" which are sure to occur. Technical skill involves, among other things, a knowledge of climatic and soil conditions, of practical methods of moisture conservation and crop rotation, and of the standard varieties of crops adapted to the conditions of the growing season.

Wheat production.—Regardless of the objections that may be offered to the one-crop system, certain sections of this state have no other alternative than to produce wheat. It may be argued that there is a surplus of wheat in the United States, *but there is no surplus of the high quality wheat that Montana produces.* Information obtained through the soil surveys makes it possible to designate rather definitely the location of the areas which are best suited to the development of strictly wheat farms, and years of research are indicating the methods of crop and soil management which will reduce to a minimum the risks involved in raising wheat on those areas which should continue to produce this crop.

Montana wheat growers should remember, however, that they must compete with producers in other states and in other parts of the world. Whether they can compete successfully depends upon their ability to grow a product of high quality and market it as economically as can their competitors. With a rich soil, comparatively free from weeds, a favorable climate, and large areas of tillable land, the technical skill of Montana operators may produce "premium quality" wheat on a low cost basis and provide satisfactory return for their labor and managerial ability.

Better crops and greater dependability in the crop have followed from the alternate wheat and summer fallow system, and this is now nearly the universal practice on the dry lands. In a windy country, however, very much damage has resulted in some years from soil blowing on the bare fallow. The use of the duckfoot cultivator and the furrow drill have checked this soil drifting to a considerable extent. Within the past few years strip farming in addition has been

recommended and limited farm experience has demonstrated its practicability on some large as well as small farms. Strips of fallow alternating with strips of grain, each 13½ rods wide, making twelve such strips to the half mile, seeded at right angles to the prevailing wind, seem to be effective in preventing the drifting. Further details on the best practice to be followed have yet to be worked out.

Combination wheat-live-stock farming on the dry land.—In many sections of the state farm land to which wheat is well adapted is interspersed with rough grass lands, suitable only for the grazing of live stock. In such areas wheat-live-stock farming combinations will probably best utilize the resources which are available, with wheat as the important cash crop and live stock adding to the farm income. However, to provide a satisfactory living for the operator and his family many of the present farms operated on this basis should be much enlarged.

Feed for live stock on the range.—Primarily Montana is a live stock state, and all planning for the future use of its agricultural lands must recognize this fact. The grass lands of the range are the mainstay of Montana's sheep and beef cattle industries. Both observation and the results of range research prove conclusively that in many instances this resource is being shamefully misused. There is need for a more universal adoption of methods of management designed to increase the present low carrying capacity of large areas of grazing land. The carrying capacity of proposed grazing districts or areas must be accurately determined and grazing so adjusted as to permit natural reseeding and revegetation. Additional water supplies must be developed, by both wells and reservoirs, in order to obtain more complete utilization of all the range areas. There are large areas of denuded or overgrazed land which need to be regrassed, by either natural or artificial means or both. Reseeding of thousands of acres of abandoned crop lands also constitutes a major range problem. The results of experiments, combined with farm demonstration, show conclusively that crested wheat-grass is one of the most promising grasses for reseeding this abandoned land. It is resistant to both drought and cold and stands up well under grazing. Seed supplies are rather limited but are increasing and plans are being worked out to simplify and cheapen the cost of seeding.

Sound land use planning, particularly for the cattle and sheep industries, will include selecting land capable of producing adequate

supplies of reserve feed in the form of hay and concentrates. These feed reserves and the increased carrying capacity of the ranges will provide insurance against the "dry years" and "hard winters" and go a long way toward placing Montana's live stock industry on a permanent and stable basis.

Farming under irrigation.—The Fifteenth Census (1930) of the United States reported 11,925 farms in Montana partly or wholly under irrigation. The area actually irrigated in 1930 was given as about 1,595,000 acres, while there were 2,276,000 acres under the ditch and capable of being irrigated. The estimates give about 3,000,000 additional acres so located that they could be irrigated, provided the cost was not economically prohibitive. The larger part of the present irrigated area is in the mountain valleys and along either side of the major rivers and streams of the state. Further extension of the irrigated areas will call for the construction of reservoirs, both large and small, for the storage of water, for low-lift pumping plants, or for long ditches to carry water from the rivers and streams to certain of the higher benches.

Irrigation makes for a dependable crop each year and under good farm practice a large crop. It also makes possible a greater variety of crops, as with a water supply available through the season crops requiring a longer period of growth may be produced. These factors contribute to a more intensive type of agriculture, with systematic crop rotations and the possibility of intelligent fertilization. I say these things are possible, though many fail in their accomplishment because the highest type of skill and experience in agricultural practice are required to attain to these possibilities.

The experiences of the past ten or more dry years suggest that much of the land that has been cropped under dry farming methods must revert to range pasture. To maintain the farmers who have been living on these lands other areas must be provided where cropping will be more dependable and this should logically mean an enlargement of the irrigated areas of the state. Wherever irrigation water is available the cropping possibilities of an area are very much increased, not alone in larger yields but in the variety of crops as compared with adjoining dry farming areas. Irrigation keeps the crops growing vigorously during the warmest season of the year and continues this growth until it is checked by frost, even if the season is very dry. Moreover, the harvesting season is usually dry, which is particularly favorable to gathering the crop in the very best condi-

tion. Again, the mountain valleys are generally more moist and always cooler than the plains area, thus providing favorable conditions for a different variety of crops. A few of these will be discussed.

Sugar beets in Montana is a crop that is dependent on irrigation as it is a long-season crop. It grows particularly well in the lower irrigated regions in the plains area of the state, and also in the lower valleys west of the Rocky Mountains. With irrigation and good cultural practice, the climatic conditions seem to be especially favorable to a high yield and a high sugar content in the beet. This crop is not well adapted to the higher valleys.

Other crops that show special adaptation to various parts of the state under irrigation are beans in the lower and warmer areas, and peas in the higher and cooler valleys. Alfalfa grows best in the warmer areas with the longer season, while the clovers, red and alsike, like the cool valleys and foothills. Tomatoes produce best in the warm, long season, while potatoes give higher yields and quality where it is cool. Even weeds illustrate the effect of the climatic differences. Russian thistle is a very bad weed in the warm, dry areas, while it ceases to be a pest in the cool regions where fanweed thrives best.

Fruit is an irrigated crop that is also influenced by climatic conditions. The growing of apples and other tree fruits as commercial crops is possible only in certain valleys in the western part of the state where extremes of temperature, both winter and summer, are limited. Only the early and very hardy varieties of apples can be grown in other parts of the state. This same picture of local adaptation may be applied to many other crops grown under irrigation in the state.

The foregoing facts lend force to the argument that further development of the irrigated resources of the state will permit the production of a great variety of products which will grow successfully and produce largely when irrigation water can be applied.

This vision of Montana's crop possibilities is based not alone on the studies at Bozeman but those at the branch stations, one in the northern part of the state near Havre, on the old Fort Assinniboine reservation; another in the Judith Basin, near Moccasin; and a third in the Yellowstone Valley, near Huntley. At the two former stations extensive series of cropping experiments have been carried on for from twenty to twenty-five years, while at the station near Huntley irriga-

tion studies in an important sugar beet area have been carried on for over twenty years. Through the years temporary crop study stations have permitted the gathering of definite information about many other parts of the state, while visits to other sections by those in charge of the crop studies have afforded opportunity to learn much about the cropping possibilities of every part of the state.

THE AGRICULTURAL ENGINEER WILL HELP

As we visualize the future agricultural development of the state, the civil and the mechanical engineer, and also the agricultural engineer, will have important parts to play—first, in the development and extension of the irrigated areas, and again in pointing out how mechanical power and machinery may become of increasing value to our farmers. This is the age of the machine, on the farm as well as in industry. Power applied to an increasingly efficient machine has so increased productive ability that now one man in a given time may produce as much of certain agricultural crops as ten to twenty men did a hundred years ago. The immediate effect of this was to reduce the number of people employed in any particular industry, but to the extent that the machine lessened the price of the goods these losses from decreasing employment might ultimately be alleviated.

The machine has taken much of drudgery from the farmer and his family, has added to the home conveniences and opportunities for enjoyment, but has pushed production beyond the demands of the market, resulting in such low prices as nearly to wipe out the farmer's income and markedly depress the value of his property. The agency eagerly sought as a help, has turned to rend him. Does this mean that we must do away with the machine on the farm? Decidedly not. Our problem is to master this machine—study not alone how to fit it into our production program but how it must also fit into the local, national, and even international economic picture.

The machine, efficiently used, will continue to find a place in agricultural production. We are not going back to the one- and two-horsepower unit, to the drag harrow, the scythe, and the cradle, and so the studies of the Agricultural Engineering Department are still necessary—studies on the efficient operation of the power unit and machines used on the farm and in the home so as to reduce expense, increase efficiency, and extend the machine's life of usefulness. We believe the farmer is fully entitled to all the machine has to offer in

reducing the time, the energy, and the drudgery which the occupation of the farmer in the past demanded.

Montana has from twenty to twenty-five million acres of land level enough to be cropped and cultivated but has sufficient water to crop scarcely more than one-third this area. From an agricultural standpoint, therefore, our great lack is a water supply—it is the great essential to a successful irrigation agriculture. We should therefore hold all possible of this water on the land and in the state and turn it to beneficial use.

In the development of the state's major irrigation enterprises the first problem is to work out plans for putting into use as far as possible all the land at present under the ditch. To develop their highest use some of these areas need additional water for late season irrigation, which can be secured only by the building of reservoirs. Accompanying this, should come the construction of reservoirs to hold back water for further irrigation development. The Fort Peck dam makes a beginning of such development but to complete the picture such a storage system should follow up the streams and build dams up to their sources in the mountains. The use of this water for irrigation will be equally efficacious in holding back flood waters and equalizing the stream flow through the season, and perhaps more so than the storage itself, as much of the water applied to growing crops finds its way into the subsoil and one, two, or three months later it flows back to the rivers and streams lower down in their course. Thus these mountain reservoirs serve a threefold purpose: first, to provide water for irrigation; next, to hold back flood waters; and then to help equalize the stream flow through the season.

There is a question whether the kind of crops that may be grown in Montana will ever warrant deep-well pumping for irrigation. Certain truck crops may perhaps be an exception. Low lifts from a comparatively standing level of a stream or well may have possibilities. An abundance of cheap electric power should make many small pumping irrigation enterprises possible and practical.

In certain places large low-lift pumping plants could serve a double purpose, namely, to drain areas swamped by seepage from irrigated lands higher up, and then to use this water to irrigate dry land not far distant. Such a pumping system, while draining certain lands, may also provide water for old water rights lower down the stream, thus releasing water farther up for holders of later rights.

Much can be done in further conservation of the water supply by the construction of small reservoirs all over the range country. All of these reservoirs should be large enough to provide water for the stock, and perhaps for a garden. Thorough investigation should be made before constructing such reservoirs, to be sure the run-off area will provide enough water. Then the site should be carefully examined to be certain that it will hold the water, and finally an ample spillway must be provided to care for any excess water without damage to the dam. Such a reservoir should be fenced to keep the water as clean as possible and water for stock should be drawn off through a pipe to a trough.

The larger reservoirs that may be constructed out in the range country may in addition provide water for irrigating a few acres up to several hundred acres of land to grow stock feed right where it is needed. From the smaller reservoirs and some places where reservoirs are not possible, a diversion dam and the construction of a ditch will carry the flood waters to a few or many acres of cultivated land and thus insure one good crop of hay from such lands, and in more favorable seasons even a grain crop. Pastures also will be improved by a system of ditches or furrows which will retard the run-off of heavy rains until the water can soak into the ground. Followed up through the years these plans for water conservation will add very much to the crop and the live stock production of the state. It may take years to complete the picture but it is surprising what may be accomplished through persistent, long-continued effort.

THE FIELD OF HORTICULTURE AND ITS FUTURE

The events of the past few years seem to be forcing on the minds of all the people in this country, and we might add, of all those in the civilized world, that we are in a transitional period out of an old and maladjusted setting into a new vision leading us to a definite change in our economic and social relationships; not immediately, but during the next generation or two.

For thirty years or over the equivalent of all the natural increase in the population of the rural areas has left the farm. Now, we find that with the break-down in the business world millions are moving back to the land to be near a food supply. Industry is looking to the possibility of getting many of its workers back on the land where supplemental work and income may be obtained.

It looks as though the farmer also will have to get closer to the soil and endeavor to make the farm produce an increasing share of his provisions. He must emphasize the thought that the farm is where he must live as well as work and that there is no other place to go for a living. It is then worth while to make this farm home the best possible place to live. It appears to me that this is an opportunity for the horticultural and home economics workers. Now is the time to push what these departments have to offer.

There is a very large opportunity in Montana for a multiplication of gardens both in size and number. The past few years the garden has been urged as a relief measure, but that should be a passing phase. It must be a permanent and increasingly important source of the family income on every farm, if we rightly interpret the trend of farm economy. If grown in ample supply, fresh fruit and vegetables will always be on hand and will markedly reduce the farmer's cash expense accounts.

Most parts of Montana are well adapted to growing vegetables. Even if the season is short, varieties are available that are adapted to those conditions and these are being added to through the work of the station horticultural department. Methods have also been devised by which even the longer-season vegetables may be grown in the short summers of our higher valleys. For instance, tomatoes may be started in a greenhouse or in a hotbed and, when transplanted to the field, may be pruned and trained to a stake so the fruit can get the full benefit of the sun in ripening. Other methods used with other vegetables bring about similar results and extend the time when the crop is available for use. By careful study of methods and proper selection of varieties, many types of garden vegetables and small fruits may be grown in all parts of Montana, if water is available, except in the very highest valleys.

Even if the logic of events as pictured above should work out, a living alone is not going to satisfy—a home is needed. A fitting slogan for our farmers, therefore, is, "It is not a home until it is planted." Trees, shrubs, flowers, grass, shelter belts, and landscaping must enter into the picture. Enjoyable surroundings must be created if dissatisfaction is to be avoided. Shelter belts are not difficult or expensive to provide and add immensely to the appearance, the comfort, and the value of the home. They also give pride of ownership and a worthwhile satisfaction to living.

The field of horticulture also affords an opportunity for a substantial and satisfactory income, even in Montana. Many other regions and states can grow similar vegetables and fruit, but in many directions we can excel in quality, while for certain fruit and other crops the lateness of our season gives a good late market for the fresh produce after the crop from other districts is used up.

The commercial production of vegetables, as a rule, will be restricted to markets in Montana and limited areas adjoining. There are possibilities of expansion with some crops through growing them for an early market and getting them to the market quickly and in the best possible condition. Being close to the market will also permit supplying it for a longer season.

The Montana-grown potato has made for itself a place of definite value. The Netted Gem, when properly grown and prepared for market, brings a price in the out-of-state market equal to the best from competing states. The best market potato is grown in the higher and cooler western part of the state. The development and expansion of the potato market will depend on using high quality seed, the proper cultural practices so as to keep costs low, and then grading the crop to the standard which the market demands. Montana will continue to produce certified seed potatoes for outside demand but expansion here is limited. The larger demand for such seed should be from the commercial potato growers in the state—a market yet to be developed.

Small fruits may be grown in nearly all parts of the state and usually coming late on the market find a ready sale for limited quantities. Of the tree fruits the sweet and the sour cherry and the apple are about the limit, and these in commercial quantities only in certain valleys west of the Rocky Mountains. Commercially sweet cherries succeed in Montana only around Flathead Lake and best on the east shore. Climatic conditions generally bring these cherries on the market later than those from other districts, when they find a ready sale. The sour cherry produces well in many parts of valleys west of the Rocky Mountain divide. There is a considerable market in Montana and states to the east for the fresh fruit, but any increase in the crop must be canned. The quality of the canned fruit is excellent.

The apple as a commercial crop is also confined to western Montana. With present land values and the comparative freedom from pests and diseases, which reduces materially the necessary spraying, the apple can be produced in the area as cheaply as in any part of

the western country. With improvement in business conditions, it should again be possible to establish the profitable outside markets of the past, while a good marketing plan, well followed up, should sell most of the crop within the state.

BETTER LIVING IN MONTANA HOMES

In looking toward the future development of Montana agriculture, there seems to be a need for more thorough knowledge of the natural resources of the state and a more efficient utilization of these resources in order that a better standard of living may be maintained by the rural population. With this for an ultimate goal, the rural home and its activities will occupy an important place in any program that may be proposed.

To bring about a better standard of rural living requires the solution of many home problems. It is in this connection that the Home Economics department of the Montana Experiment Station feels that it may render assistance to the rural homemakers of the state through the scientific study of these problems.

While the standard of living in a rural home is somewhat dependent on the amount of financial support received from the operation of the farm, yet it is greatly influenced by the efficiency with which available resources are utilized.

With planning and care, many of the foods for the family's use may be produced by or secured from the farm. These include vegetables, fruits, native fruits, meats (such as lamb, mutton, beef, and pork,) poultry, fish, game, dairy products (such as milk, cream, butter, and cheeses), meat fats (especially lard), eggs, and cereal grains. Not only is it essential that the rural family should know how to produce these foods and secure the best results, but they should also know how to use them most advantageously. That involves an understanding of the relative nutritive value of foods, particularly the mineral and vitamin content, and how to prepare them so they will retain their nutritive value. The conservation of many of these foods for winter use needs further investigation to compare the relative merits of storage, canning, drying, salting, curing, preserving, fermenting, or freezing. During the past eight years the Home Economics Department has already started a study of the effect of storing, canning, drying, and salting on the nutritive value of some of the Montana vegetables. It is planned that this kind of investigation may be continued until it includes a complete survey of Montana-

grown foods, with respect to their nutritive value, both before and after various kinds of treatment.

Along with food production and utilization comes an interest in nutrition or the effect of food upon health. The growth and development of children and the general good health of adults are closely related to the kind, quality, and amount of food used regularly. When such irregularities as dental caries, simple goiter, eye disturbances, obesity, leanness, and rickets occur frequently in families or in communities, the Home Economics department would like to investigate the possible relationship between these conditions and the food supply.

The rural homes in Montana have many opportunities to utilize the power and fuel resources in the state. Gas, oil, gasoline, wood, coal, water power, wind power, and electric power occur quite generally. This department could very well cooperate with the Agricultural Engineering department in studying the relative economy in using these sources of power and fuel for cooking, heat, and the operation of equipment in the rural homes. Such investigations would necessarily include comparative studies of home equipment and expenditure of time and energy by the homemaker.

Assistance might be given in the utilization of the family finances by suggestions regarding budgeting, keeping accounts, and consumer buying. Information already assembled from the household accounts of forty rural families in Montana would aid in formulating such suggestions. Studies of textiles and their wearing qualities, such as the present investigation of the durability of silk hose being conducted by this department, would help the consumer.

There are other resources of less obvious nature that might be developed to benefit the rural homes of the state along social lines. The building up of community interests in education, recreation, and religious activities would also do much to bring about better standards of living.

THE CHEMIST'S CONTRIBUTION TO A PROGRESSIVE AGRICULTURE

The aid of chemistry is all-important to the progress of agricultural research and to the explanation of many agricultural problems. This department of the Experiment Station has been giving special study to the proteins of wheat and to the effect of phosphate and other fertilizers on plant growth and development. The protein content of wheat has a very definite relation to the price paid for it. These studies are looking toward finding the factors contributing to this quality and how these can be controlled. Montana can continue to grow wheat with greatest profit if she can depend on producing it with a high protein content. Progress has been made in this study but much yet remains to be done.

From the agricultural standpoint the soil is the fundamental resource. A more accurate statement, however, would be that the soil is the storehouse for the food necessary to the growth and development of the plant, the home of multitudes of micro-organisms which make this food available to the plant and the medium in which the plant grows. The chemical studies which supplement the soil surveys give definite facts about the amount of certain plant food compounds in the soil. By fertilizer tests carried out on various soil types and with different crops in many parts of the state, very much has been added to the knowledge about Montana soils and the treatments needed to control fertility and to maintain crop yields.

These studies indicate that for cereal crops and certain vegetables phosphorus fertilizers tend to improve quality and hasten maturity. If the soil is somewhat deficient in phosphorus the yield may also be markedly increased by adding phosphate fertilizer. A typical illustration with spring wheat showed an increase in yield from 33.3 to 44.1 bushels per acre, or an increase of 10.8 bushels per acre from applying phosphorus where it was deficient. The cost of the fertilizer was $3.50 per acre. The first crop does not show all the benefits; the application also helped the next year's crop grown on the land, when the residue of phosphorus increased the wheat crop by 6.4 bushels per acre.

Phosphate also markedly increases the yield of sugar beets on many soils. One typical test with an application of 100 pounds of phosphate per acre gave 10.8 tons of beets without the phosphate and 21.6 tons with it, or essentially double the yield. Phosphate fertilizers on many soils also increase the yields of such crops as alfalfa, sweet

clover, and peas. We find, too, that the hay made from these crops is much improved in its phosphate content when they are grown on phosphorus-deficient soils. This is an indirect but very satisfactory method of supplying the phosphorus to cattle in areas where the bone-chewing habit has been formed. The increase in yield from the use of phosphorus was 1,330 pounds per acre for the alfalfa and 3,500 pounds for the sweet clover plot. These results, however, were not obtained from the same type of soil.

Another striking result from the use of phosphorus on the alfalfa and sweet clover was a marked increase in the nitrogen stored by the plant. With the alfalfa crop it was found that when phosphate was applied about 73.7 pounds of nitrogen per acre was found in the alfalfa, whereas when phosphorus was not applied but 41.3 pounds per acre was removed by the crop. With sweet clover phosphorus increased the nitrogen content of the acre crop from 18 pounds to 83.15 pounds. All these crops were grown under irrigation.

This is not the whole story, however. Previous studies by the Experiment Station had shown that the application of phosphorus had hastened the maturity of such crops as grains, many vegetables, and certain fruits. The effect of phosphorus applications to peas, alfalfa, and sweet clover in a series of tests the past season was to delay the maturing of these crops, an effect directly opposite to the effect on non-leguminous crops. Whether all leguminous crops would act similarly is a matter for future investigation. An explanation that seems reasonable is that the phosphorus stimulated the growth and activity of the nitrogen-gathering bacteria in the nodules on the roots of these leguminous plants and made available an abundant supply of nitrates to these plants, thus stimulating their growth. The effect was the same as is obtained with a generous application of nitrates to the soil. The phosphorus was probably also a direct factor in the more vigorous growth of the crop apart from its indirect action in stimulating the accumulation of nitrogen. Records available give no previous report of this indirect applying of nitrogen to leguminous plants and the delaying of their maturity through the application of phosphate fertilizers. These and other additions to our knowledge about agricultural crops add to our control of their yield and quality and are very important factors in agricultural progress.

PLANT PATHOLOGY AND THE FORWARD LOOK

Plant pathology may be defined as a study of the diseases of plants, the diagnosis or identification of these diseases, and their control. Questions are continually coming to the department of botany and bacteriology, inquiring as to certain plant conditions which indicate lack of thrift or some abnormal appearance, and asking what is the trouble and how it may be overcome. The first task is to determine the cause of the trouble. Perhaps the information gained through the years by other investigators as to the disease and reported on by them at various times may permit an immediate answer to the inquiry, but new difficulties are continually coming up or old ones are appearing in a new form and then the problem must be investigated. It is first necessary to study thoroughly the infection and its probable cause. Next, the environmental conditions should be examined, including the soil, the temperature, moisture, aeration conditions, degree of light exposure, etc., etc., that are favorable or unfavorable to the disease. We must then find an antidote or a method of control before the task is finished.

Some idea of the scope of such an investigation may be had from the factors that research has demonstrated should be considered in controlling bunt in wheat, which causes a loss of approximately 4 per cent of the wheat crop of the state and on some farms much exceeds this. The first preventive is to select clean seed. Such may have to be obtained from a field which the previous year was free from the disease. Even if this is possible, however, a second control measure should be applied and the seed treated to destroy the spores of the disease that may adhere to it. With bunt the wheat should be thoroughly treated with copper carbonate, formaldehyde, or organic mercury compound. Next, do not plant the wheat in a field known to be badly infected with this disease the previous year, because we find that the spores of bunt live in the soil over the winter and will infect the wheat sown in such soil.

If there are only a few diseased plants in a field, then a fourth method of elimination may be by pulling and destroying them. However, while this is a good plan for certain diseases of the potato, it is scarcely practical for wheat except in small plots.

Another method of overcoming bunt is by the breeding of resistant strains of wheat. This is possible but difficult; first, because in addition to resistance to infection we must retain good yield and high

quality; next, we find that there are many strains (physiological forms) of bunt and while one variety or strain of wheat may be resistant to certain forms of bunt it may not be to others. Work is in progress on this problem.

The most complete control of bunt is possible only when the farmers of a district cooperate and all work at this problem, otherwise infection travels from farm to farm, especially through the community threshing machine.

Finally, we find weather and its changeableness during the year is an important factor in bunt control. For instance, the spores of bunt grow only when the mean soil temperature ranges from 35 to 40 degrees Fahrenheit, and essentially not when the soil is warmer or colder than this. Practically the winter wheat sown between August 1 and September 5, when the soil is warm, is usually comparatively free from bunt. When sown between September 5 and October 20 the soil temperature is favorable to bunt infection, but later in the season there is again very little infection. It is believed that with the yet more complete knowledge of the factors affecting the bunt spores, control measures may become more effective and less costly.

These facts illustrate how many factors must be considered in working out control measures for our plant diseases. They look simple when brought together in this way and they must be simple if they are to be effectively applied by the farmer, yet to gather all these facts and test their application has taken many years and the work of many scientists in many countries. The study of some diseases is yet more complicated as the cause is not so apparent as with bunt.

There are many plant diseases which we do not know how to control and especially how to control them most effectively and most completely. Again, with the exchange of commodities between this country and all parts of the world new diseases are coming that may seriously injure certain crops, sometimes much more seriously than in the countries from which they come, of which we have many illustrations. Continuous study and investigation is therefore necessary if adequate protection is to be given to our crops.

THE FUTURE OF ENTOMOLOGICAL WORK IN MONTANA

In spite of the great change in emphasis which may be given to the various units of our agricultural production program, it is believed that due to our varied climate, to irrigation, and no doubt to other factors such as the intractable nature of the human species, there will be little probability that the types of crops and live stock as at present produced are going to disappear from the agricultural activities of this state. No doubt small grains, forage, and live stock will continue to contribute by far the greater part of our agricultural income, but other products such as fruits and vegetables will still be extremely important to the livelihood of a considerable part of the population and indeed many of them very important to the well-being of the people. Our insect problems of the future we believe, therefore, will closely coincide with their importance in relation to these types of production.

As another principle on which to base a survey of future entomological needs, it should be pointed out that investigational work in this field is not of transient value. While it is true that our insect problems change in importance with changes in our agricultural scheme, none of the work is lost, even with basic changes in our agriculture, but serves as part of the general foundation for all future research on insect problems.

The major pests of the small grains are grasshoppers, the army cutworm, and the pale western cutworm. The greatest entomological service in controlling these insects can be rendered by predicting the time and place that they will reach destructive numbers. Control of the pale western cutworm depends almost entirely upon advance knowledge as to its possible abundance. This insect strikes only occasionally but, when it does, enormous crop losses result. While in some of the years of pale western cutworm abundance, the crops would be lost any way on account of accompanying drought, yet advance knowledge makes it possible for the farmer to put into practice cultural methods which will prevent serious crop destruction.

Prediction studies depend for their accuracy on weather data, except in the case of grasshoppers where actual egg counts in the fall are the best index of a coming outbreak. At present the number of volunteer weather reporting stations in Montana is very small compared with the extensive areas concerned. Very great differences in weather conditions over a distance of but a very few miles occur in

some counties. Weather data collected from only a few stations may result in false and misleading conclusions in our prediction work. If weather conditions could be studied rather intensively in two or three counties over a period of five to eight years, an opportunity would be provided to test out predictive methods in a way that would be very sound and no doubt productive of important results. Likewise these data should prove of interest in other fields of agricultural study.

The major insects attacking field crops are the insect carriers of bean mosaic, the pea aphis, and the sugar beet webworm.

As the mosaic disease of beans is the greatest limiting factor in bean production in Montana, the insects responsible for transmitting the disease from plant to plant become very important. This problem involves some complicated relationships but progress is being made and methods of eliminating the insect vectors from bean plantings can no doubt be worked out.

Montana has an advantage in pea production in that certain insect pests do not occur here. Although the pea aphis is present, it does not cause the extensive losses to this crop that occur in other important pea-growing states. As no direct methods of control for this insect have proved at all satisfactory, the most promising line of attack is through the artificial and natural cultivation of its predaceous enemies. It has been observed a number of times in Montana that the pea aphis can reach enormous abundance, but the rapid increase of Coccinellid (ladybird beetle) larvae and adults cuts down the losses which would otherwise occur. There is little doubt that this area is favored by the natural occurrence of these predators. It is entirely possible that their artificial propagation so as to head off expected aphis outbreaks would be very desirable in Montana.

Although the pea weevil will develop in occasional years in this state, yet in the greater part of our pea-growing area the weevil is of negligible importance. This is a decided advantage to the seed-pea industry but even more of an advantage from the standpoint of the production of canning peas.

Insects troubling truck crops, greenhouse crops, and home gardens are too numerous to mention. For the most part there is no lack of knowledge of means for their control. One aspect has recently become important and may be even more of a factor in the future—the matter of finding substitutes for the arsenicals commonly used in the past in preventing damage from many insects affecting

these crops. Fortunately the availability of the alkaloidal poisons, which are highly toxic to insects but practically innocuous to man, has increased rapidly during the past few years. These substances offer the best possibilities of control for a great number of truck crop insects without any danger from human poisoning due to any residues which may remain on the plants.

Control of the major insect pests of live stock, such as ticks, lice, bots, and warbles, involves the cooperation of the entomologists, the veterinarians, and the Livestock Sanitary Board. For ticks and lice the methods of control, though adequate at present, could be greatly improved. To a large degree their control depends on the availability of dipping vats more than on anything else. The experience of live stock men in the Bitter Root Valley is worthy of note. Beginning in 1913, regulations compelling the dipping of all animals exclusive of dairy cows, in certain areas were set up in the valley. Few cattle were dipped during the first few years. Gradually it became noticeable that the animals dipped in the spring were several weeks ahead of undipped stock in thriftiness by the middle of the summer. Dipping has become more and more popular until now a rather high percentage of all the live stock in the valley is dipped each year. In addition to working out as a control for spotted fever, this dipping project has proved valuable for the live stock purely because of the improvement in condition resulting from the destruction of their external parasites.

While the control of bots and warbles is largely an extension or regulatory proposition, nevertheless more information relative to these insects, as well as black flies, horseflies, and other species which torment horses and cattle, would serve as a valuable foundation for control operations.

The insects that damage shade trees, shelter belts, and ornamentals we as yet know little about. As our agricultural region becomes older, as fewer people enter into the occupation from a speculative standpoint, and more attention is paid to living conditions and their improvement, the matter of trees, shelter belts, and ornamentals, takes on increasing importance. No more valuable piece of work so far as the interests of all the people of the state are concerned could be undertaken than a broad study of all the insects affecting shade and shelter belt trees.

MONTANA WILL CONTINUE TO PRODUCE LIVE STOCK

The live stock industry of Montana represents one of the state's major industries. It supports approximately one-half of the state's population, utilizes three-fourths of the state's area, represents a capital investment of over forty million dollars, and returns a gross annual income that has averaged over fifty million dollars during the past five years.

This annual income represents to a large degree the conversion by live stock of feeds such as grass, hay, and grains into edible human products such as beef, mutton, pork, milk, and eggs. Through live stock are marketed products that would otherwise yield very little income to the farmers of the state. An industry of this importance needs some thought and planning for the future.

A permanent live-stock industry is dependent upon a reliable water supply, ample feed, disease control, efficient management, the production of animals that most nearly meet the market's requirements, and then satisfactory prices.

Grass, the most abundant feed crop in Montana, is produced over millions of acres of the state. The problem of a majority of our live-stock producers is to make the most efficient use of this grass. From the standpoint of meat production, cattle and sheep convert grass into meat more effectively than any other class of live stock with the result that the state has a large cattle and sheep population. The most efficient use of our grass lands, however, calls for more than just turning cattle or sheep out to graze. Limiting the number of head of live stock grazed on a given area to the feed available will give much the largest returns from this grass when measured in meat production. This method has the additional advantage of maintaining and improving the pastures. Along with controlled grazing can also come improvement in the kind of cattle used for grazing, again resulting in increased gains both from the steers fattening on grass and from the weaning weights of suckling calves. The ability to fatten in the best way is a character that can be bred into cattle, hence more attention to natural fleshing will result in more quality beef from a given amount of feed. This is the opportunity for breeders of pure-bred stock, who supply most of the range bulls, to improve the commercial herds. They can serve the state best by producing these pure-bred cattle of high quality needed by the commercial operators.

In discussing the improvement of type, quality, and natural

fleshing of cattle, it should be kept in mind that common cattle have been, and no doubt will continue to be, fed at a profit in many instances, but with such cattle usually the feeder's profit is the breeder's loss. Montana will probably continue to breed feeder's cattle for Corn Belt feeders although increased interest is being shown in fattening cattle on grass.

Cheapening production costs through economical wintering of the breeding herd adds to the financial stability of the cattle enterprise. Data gathered at the Northern Montana Branch Experiment Station indicate that limiting the roughage for breeding cows does not affect the birth or weaning weights of the calves and that heifers to be used for future breeding cows can be wintered as calves, yearlings, and two-year-olds on a limited amount of roughage without materially affecting their growth or mature weight, provided ample pasture is furnished during the grazing season. The smaller winter gains made by heifers on limited roughage are usually made up by greater gains on pasture.

A sufficient supply of winter feed is necessary before any permanent live-stock industry can be developed, but wintering the breeding herd is expensive and money saved in this connection without injury to the development of the calves helps to reduce losses or increase profits.

The dry-lot fattening of cattle in this state is closely confined to irrigated areas and sections where beet pulp is available, and no doubt will continue to be. The fattening of cattle on grass, while one of the state's oldest methods of producing beef, is also limited to certain areas. There is again a growing tendency to make greater utilization of grass for this purpose.

From the standpoint of a permanent cattle industry for the state, the less speculative the more permanent the operation. There are two contrasting methods of cattle production; one calls for the purchase of both feed and cattle, a system under which men have made and lost heavily as it requires speculation as to the price of both cattle and feed; the other method is that in which the producer grows what he feeds and feeds what he grows. This method is the least speculative as the operator markets what he produces both in the form of live stock and of feed. With this method, an ample feed supply is necessary both for carrying the breeding herd and for fattening the cattle. More attention will be paid to fattening cattle because, while it is primarily a cattle breeding state, Montana has some advantages

over the Corn Belt producer in finishing cattle on grass. The more nutritious grass and the cool nights are both favorable to greater gains. The probable trend of the Montana cattle industry will be either the production of more good quality feeder calves and yearlings for the Corn Belt producers, or a reduction in numbers of breeding cows and the sale of the home-grown calf as a grass-fat steer. This steer may not be a market topper but topping the market does not necessarily mean a profitable feeding operation. While there will always be operators who will buy cattle to finish out on grass or in the feed lot, yet the majority will continue the cattle breeding. To carry out such a program to its fullest possibilities, however, the water supply must be improved, the winter feed reserve increased, the grazing on the pastures controlled to insure more beef for a given area, and finally the cattle must be improved to get the largest gains from a given amount of feed.

Many of the comments made above regarding a permanent cattle industry apply also to the sheep business. However, two other factors should be considered, namely, the wool production and the lamb production. While we can market our cattle as yearlings or two's, the market discriminates very severely against the wether, while it demands and will pay extra for the fat lamb as finished by the producer or for the feeder lamb to be finished in the feeding areas. Black-faced lambs are preferred on the market but wool values, herding qualities, and grazing ability demand a measure of merino in the range ewe.

Hogs, while playing a minor part in many sections of the state, have been profitably produced in regions where grain farming is established and will no doubt be closely associated with the dairy cattle industry, which occupies an important place in the irrigated areas of the state.

Horse production can be successfully carried on in both the range and irrigated areas. On the smaller irrigated farms, horses furnish an economical source of farm power and bring in additional revenue through the sale of surplus stock. While horses should not be produced in too large numbers, enough should be raised to supply the replacement for farm power. The economical method by which range horses can be produced should enable breeders to compete very successfully with the Corn Belt farmers, provided they raise the right type of horse. The day of the ton gelding is about over, the fourteen to fifteen-hundred-pound farm chunk being most in demand.

FITTING MONTANA INTO THE NEW DAIRY SETTING

Dairying forms one of the important industries in Montana, particularly in the irrigated valleys where an abundance of alfalfa hay and small grains can be grown comparatively cheaply. The western part of the state, located nearer the state's consuming area, is well adapted to dairying. The distance from the larger consuming markets, however, is one of Montana's marketing handicaps for dairy production. This is partially offset by cheap feed of high quality, good pastures under irrigation, and favorable summer climatic conditions.

One effect of the agricultural and economic depression has been to compel a restudy of the economics of milk production. The Bureau of Dairy Industry, United States Department of Agriculture, in cooperation with the Montana Branch Station at Huntley, points out that cows fed on roughage alone, while producing less milk yet produces it at much less cost than when fed grain with roughage. One hundred acres planted to alfalfa will produce more nutrients and will feed more cows than if used to produce the grain and hay needed to provide what has been considered a standard dairy cow ration; or, put in another way, the cost of the nutrients in a roughage ration was but 56 per cent of their cost in a full-grain ration. Feeding roughage only applies especially to this period of low prices and an oversupplied market. Such a feeding practice, of course, calls for good pastures throughout the summer and well-cured roughage of high quality for winter feeding. Under Montana climatic conditions the irrigated farm is very favorably placed to take full advantage of the facts brought out by this study. Irrigation makes possible fresh and luxuriant pastures throughout the growing season, while irrigated alfalfa provides large crops of high quality winter forage, which may be almost perfectly cured in the dry summers of the state. This is a possibility of which the irrigated areas of Montana should take full advantage.

THE WORK OF THE VETERINARY RESEARCH LABORATORY

This laboratory was established to work out methods of control for the diseases that affect or may affect the live stock of the state. Montana's live-stock industry has changed much in the past thirty to forty years. In the earlier years it was almost wholly a range industry of a relatively simple type. The breeding herds were few and many of the cattle were shipped in from the south as two-year-olds to be grown out and finished on Montana grass. A large pro-

portion of the sheep on the range were wethers, which reduced care to a minimum; while the range horses looked out for themselves both summer and winter. In those early days the range was a wide open country and cattle and horses largely roamed at will.

The past thirty years have brought the settler, who spread over this range country, fencing his holdings, and the open range ceased to exist. Possibly as a result of this but perhaps inevitably, a decided revolution has been and is going on in the live-stock industry of the state. The horse has disappeared as an asset and has become largely a parasite on the range. The three- to five-year-old steers and wethers now make up but a small part of the range live stock. The core of the range industry has shifted largely to the cow and calf, the ewe and lamb, a much more intensive type of range industry than that of the earlier days.

Again, with the agricultural development of the state there has been a large increase in other types of live stock, namely, the dairy cow, hog, and poultry, which require closer control than even the new set-up on the range. There has been a large increase in the herds of pure-bred live stock of many kinds in the state as the years have passed.

All of these changes have brought with them an increase in the troubles that have called for the services of the veterinarian and many that are new are demanding study and investigation. It was out of this increased need that the stockmen and farmers of the state secured appropriations to establish the Veterinary Research Laboratory with an enlarged staff for the study of animal diseases.

The answers to Montana's live-stock disease problems can not be obtained from other sources as the diseases of the western range country have not been sufficiently investigated. In cattle diseases there are yet many problems to be studied. Infectious abortion, for instance, has been extensively studied all over the world, but with cattle on the range this condition presents a control problem which has not yet been solved. Animal parasites are also becoming very important factors in the health of the live stock but here again the available information from any source is not applicable to range live stock. The study of mineral deficiencies on the ranges and in certain valleys of the state seems to be an increasing difficulty as time passes. This problem will require the cooperation of the Veterinary and the Animal Husbandry departments. The laboratory has already made a place for itself in the investigations of diseases of the range sheep and in

working out methods of control. New problems, however, are still arising with sheep for which no investigators have as yet found a solution.

THE STATION STAFF

Several members of the staff severed their connection with the Experiment Station during the year 1933. Professor Louis Vinke, who had been connected with the station for ten years, first as assistant in the Animal Husbandry Department and later as head of the department, resigned in the spring to accept a position in the commercial field. Mr. Vinke rendered most excellent service to the institution. This position was filled by the appointment of Professor D. W. Chittenden of Missouri. Mr. Iver J. Nygard, assistant chemist, Mr. D. M. Feese, assistant in the Grain Inspection Laboratory, and Mr. T. T. Chaddock, assistant in the Veterinary Research Laboratory, resigned at the beginning of the fiscal year. Later in the year Mr. A. G. Goth resigned as assistant agronomist. Mr. R. E. Wall, assistant entomologist, died in the summer of 1933. He had been connected with the Montana Experiment Station for two years and had fully demonstrated his worth.

During the year Professor E. A. Starch returned from leave of absence and was later made acting head of the Department of Agricultural Economics in place of Professor M. L. Wilson, who was granted leave of absence on the request of Secretary H. A. Wallace, of the United States Department of Agriculture.

STATION FINANCES

The State Legislature of 1933 reduced the appropriations to all branches of the Experiment Station work by about 40 per cent as compared with those of two years before. For one line of work no appropriation was made, namely, the detailed soil survey, and so this work had to be discontinued. This reduction in resources was met by dropping certain members of the staff, by curtailing the research work to some extent, and by a reduction of 20 per cent in the salaries of the staff.

The year started with much uncertainty as to the federal grants for the station work. The first proposal was the complete elimination from the federal budget of the grants for agricultural research work in the state. This was later reduced to a 25 per cent cut in the amount. However, the application of this was postponed until March, 1934, and finally the proposal was eliminated altogether, but it left

finances for the station work in an uncertain condition throughout the year.

Montana has been fortunate in its relations with the United States Department of Agriculture in working out agreements for cooperative studies on various agricultural problems over the state. During the past year, however, the funds of the various federal bureaus have been materially reduced and so, of necessity, have been their contributions to our cooperative projects. The emergency problems growing out of the depression, on the other hand, have necessitated calls for special services from many of the Experiment Station workers. While the financial situation during the past year has been very unsatisfactory, yet, as matters developed, temporary funds have been made available, so no serious injury resulted to the progress of our studies.

The branch experiment stations have continued operation during the year, though with much reduced funds both from the state and from the United States Department of Agriculture. The result has been a considerable reduction in the work at these stations. This is unfortunate as they provide a special and important service in the study of problems peculiar to the soil and climatic conditions of the area in which they are located.

During the past ten years the appropriations and grants to the state-owned branch stations have been reduced fully 60 per cent. For the work that has been carried on they have never been generously supported while practically no funds have been provided toward building up the plant or improving the grounds at these stations. The funds have been so limited that it was thought best to put all of them into the research work. From funds made available through the federal Civil Works Administration it may be possible to take care of certain very much needed repairs at some of these branch stations.

PUBLICATIONS

The publications of the Experiment Station for the past year include fifteen bulletins, three circulars, and ten technical articles. The bulletins and circulars were printed in editions ranging from 2,000 to 5,000 copies and, with the annual report, make a volume of 656 pages.

Since the last annual report the following publications have been issued.

BULLETINS

No. 270. Eight Years' Work by the Montana Grain Inspection Laboratory. Clyde McKee, W. O. Whitcomb, W. D. Hay, and D. M. Feese. 3,000 copies, 52 pages.

No. 271. The Use of Time by Rural Homemakers in Montana. Jessie E. Richardson. 2,000 copies, 28 pages.

No. 272. The Flaxseed Market and the Tariff. Roland R. Renne. 2,000 copies. 71 pages.

No. 273. Soils of Toole and Liberty Counties. L. F. Gieseker. 2,000 copies. 52 pages.

No. 274. Soils of Glacier County. L. F. Gieseker. 2,000 copies, 53 pages.

No. 275. Maintenance of Beef Cows for Calf Production. Louis Vinke and W. F. Dickson. 5,000 copies, 36 pages.

No. 276. The Effect of Storage and Canning Upon the Vitamin Content of Carrots. Dorothy Douglass Langley, Jessie E. Richardson, and Erlene Jacobs Andes. 2,000 copies, 32 pages.

No. 277. The Effect of Storage on the Palatability and Vitamin Content of Rutabagas. Jessie E. Richardson and Helen L. Mayfield. 2,000 copies, 12 pages.

No. 278. Farm Organization as Affected by Mechanization. E. A. Starch. 2,000 copies, 102 pages.

No. 279. A Comparison of Irrigated and Non-Irrigated Seed Potatoes. F. M. Harrington. 3,000 copies, 12 pages.

No. 280. Experiments with Phosphate Fertilizers on Montana Soils. Edmund Burke, Iver J. Nygard, and William McK. Martin. 3,000 copies, 52 pages.

No. 281. A Diker-Ridger. H. E. Murdock. 2,500 copies, 12 pages.

No. 282. Feeds for Dairy Cattle. J. O. Tretsven. 5,000 copies, 20 pages.

No. 283. Composition of Montana Feeds and Forages. Jesse Green. 3,000 copies, 24 pages.

No. 284. Small Grains and Supplements for Fattening Fall Pigs. Louis Vinke and Barton Bergstedt. 4,000 copies, 24 pages.

CIRCULARS

No. 140. Worms in Hogs. Montana Veterinary Research Laboratory. 5,000 copies, 8 pages.

No. 141. Intestinal Worms in Poultry. Montana Veterinary Research Laboratory. 5,000 copies, 8 pages.

No. 142. Intestinal Worms in Sheep. Montana Veterinary Research Laboratory. 5,000 copies, 8 pages.

ANNUAL REPORT

Fortieth Annual Report: A Forward Look. F. B. Linfield. 5,000 copies, 50 pages.

TECHNICAL PAPERS

The amount of plant food used by leaves and early growth of apple trees. Edmund Burke and H. E. Morris. Plant Physiology 8:537-544, October, 1933.

A soil temperature installation. G. Allen Mail. Soil Science 35:285, April, 1933.

Temperature as a possible limiting factor in the northern spread of the Colorado potato beetle **(Leptinotarsa decemlineata)**. G. Allen Mail and R. W. Salt. Jour. of Economic Entomology 26:1068-1075, December, 1933.

The serological identity of strains of **E. rhusiopathiae** of ovine and porcine origin. H. Marsh. Jour. American Veterinary Medical Assn. 82:584-586, April, 1933.

Experimental erysipelothritic arthritis in lambs. H. Marsh. Jour. American Veterinary Medical Assn. 82:753-766, May, 1933.

Relation of refractive index, freezing point and electrical conductivity of cell sap to the maturity of green peas. William McK. Martin and Wilber Brotherton, Jr. The Canner, June 10, 1933.

Apparatus and methods for determining carbon dioxide in continuous gas streams. William McK. Martin and Jesse R. Green. Industrial and Engineering Chemistry 5:114, March, 1933.

Home canning of peas at higher altitudes. Jessie E. Richardson, Helen L. Mayfield, and Mary Evans. Read at convention of American Home Economics Assn. Abstract in Jour. of Home Economics, October, 1933.

A strain of clostridium welchii producing fatal dysentery in lambs. E. A. Tunnicliff. Jour. of Infectious Diseases 52:407-412, May-June, 1933.

Injury to apple by petroleum-oil sprays. P. A. Young and H. E. Morris. Jour. of Agricultural Research 47:505-522, October 1, 1933.

METEOROLOGICAL REPORT FOR 1933

The meteorological records kept are those of maximum and minimum temperatures, wet and dry bulb thermometer readings (twice daily), evaporation, precipitation, wind velocity, wind direction, and hours of sunshine.

Temperature.—The year started out cold with a mean temperature of 3.1 degrees below normal. February continued cold, with a daily minimum of –36 degrees on the 19th and a mean temperature of 7.1 degrees below normal. The thermometer dropped to –36 degrees on December 9, 1919. These are the two coldest temperatures recorded since 1900 when our records began. The weather warmed up some during March when the mean temperature was 3.8 degrees above normal. The mean temperature for April was only 1.3 degrees below normal. The temperature for May was favorable for vegetative growth, being 6.8 degrees above normal. This warm weather continued through June and July when the means were 6.5 and 5.4 degrees, respectively, above normal. The mean temperature for Aug-

ust was only 0.1 degree above normal. The rains that fell during August tended to reduce the mean, yet it did remain slightly above normal. The mean temperature for September was again slightly above normal by 1.2 degrees. The mean temperatures for October, November, and December were above normal by 5.4, 4.5, and 10.8 degrees, respectively. The temperature for December was the warmest since 1896 when the mean was only 0.3 degree higher. The nearest approach since 1900 was in December, 1925, when the normal was 3.8 degrees lower than in December, 1933. The high temperatures for June and July, when vegetation was making its most rapid growth, coupled with high winds and low humidity, made conditions unfavorable for maximum yields. They did, however, hasten growth and maturity of crops.

Precipitation.—The precipitation for January was 0.08 inch below normal; February, 0.09; and March, 0.20. It is evident that these months did not furnish the normal amount of snow in the mountains to supply irrigation water. However, the precipitation which fell during the months of November and December, 1932, should be considered when studying the total water supply for 1933. The precipitation for November was 0.09 inch above normal and for December, 0.34 inch below normal. This makes the precipitation which fell during the winter months of 1932 and 1933 below normal 0.62 inch. The high temperatures of June and July soon melted the snow in the mountains, and this resulted in a scarcity of water for irrigation.

Evaporation.—The three factors controlling the rate of evaporation are wind velocity, temperature, and humidity. These factors may act concurrently, in which case we get the greatest evaporation, or it may be that there is a low wind movement coupled with a high temperature, in which event one factor is opposing the other; or it may be that a high wind movement is opposed by low temperatures and high humidity. Any one of these factors opposing will lessen the rate of evaporation. The wind movement is not influenced by temperature or relative humidity. There is, however, a connection between temperature and humidity. High temperatures are generally coupled with low humidities and vice versa.

Our evaporation records are kept from April to October, inclusive, and date back to 1916. The evaporation for April was 0.161 inch above normal, brought about by a wind velocity of 3.6 miles per 24 hours more than normal. The mean temperature for the month was below normal and the relative humidity was 1.2 above normal. Here

we have two factors opposing rapid evaporation while the increase in wind velocity was tending to increase its rate.

The evaporation for May was 0.302 inch above normal. The conditions affecting evaporation were temperature 6.8 degrees above normal, wind velocity 17 miles per 24 hours above normal, and relative humidity 1.3 above normal. In this case the high temperatures were responsible for the excessive evaporation.

The evaporation for June was 2.623 inches above normal. During this month the mean temperature was 6.5 degrees above normal, the wind movement per 24 hours was 27.7 miles above normal, and the relative humidity was 7.8 below normal. Here all three factors were acting in favor of increased evaporation.

The evaporation for July was 2.724 inches above normal. The mean monthly temperature was 5.4 degrees above normal, the wind movement was 18 miles per 24 hours above normal, and the relative humidity was 9.2 below normal. Here again all three factors were working together.

For the month of August the evaporation was 0.204 inch below normal. The mean temperature was only 0.1 degree above normal, the wind movement was 13 miles per 24 hours above normal, and the relative humidity was 1.9 above normal. In this case temperature can be disregarded; the subnormal evaporation was caused by the high humidity which more than offset the increased wind velocity. The high humidity is accounted for by the heavy rainfall for the month.

The evaporation for September was 0.055 inch above normal. The mean temperature was 1.2 degrees above normal, the wind movement was 17.2 miles per 24 hours above normal, and humidity was 4.7 below normal. Here is a discrepancy which can be accounted for only by the fact that from the 23rd to the 26th, inclusive, there was freezing weather accompanied by 7 inches of snow, a condition which made readings impossible.

The evaporation for October was 1.28 inches above normal. The mean temperature was 5.4 degrees above normal, the wind velocity was 6.2 miles per 24 hours above normal, and the humidity was 4.7 below normal. This is another case where all three factors operated together.

These evaporation records and the causes of fluctuations are of value in studying precipitation records of any locality. It is quite evident that an inch of precipitation does not have a constant value, but its value is influenced by the factors already named.

METEOROLOGICAL SUMMARY FOR 1933

BOZEMAN

Highest temperature	97°, July 25
Lowest temperature	–36°, February 9
Greatest range for year	133°
Highest monthly mean	69.5°, July
Lowest monthly mean	15.5°, February
Highest daily mean	80.0°, July 25
Lowest daily mean	–27.5°, February 9
Mean temperature for the year	43.8°
Greatest total precipitation for one month	3.48 inches, August
Least total precipitation for one month	0.34 inch, November
Total rainfall	15.89 inches
First killing frost	September 23
Last killing frost	May 12
Number of clear days in year	95
Number of partly cloudy days in year	204
Number of cloudy days in year	66
Days with 0.01 inch or more precipitation	97
Total evaporation from April to October, inclusive	46.004 inches

FINANCIAL SUMMARY

EXPENDITURES OF THE MONTANA AGRICULTURAL EXPERIMENT STATION FOR THE YEAR ENDING JUNE 30, 1933

	Hatch Fund	Adams Fund	Purnell Fund	State Appropriations and Miscellaneous*
By salaries	$ 9,651.41	$11,425.48	$39,504.07	$ 53,714.90
Labor	1,646.33	1,759.88	10,111.96	27,819.00
Supplies and materials	1,153.31	673.23	2,224.90	19,060.15
Communication service	7.78	.60	47.25	1,706.26
Travel expense	33.74	566.96	4,206.81	5,661.57
Transportation of things	6.61	9.35	174.75	632.23
Publications	58.64	—	663.53	4,500.29
Heat, light and power	34.70	11.93	78.50	3,087.33
Contingent Expense	6.49	2.27	26.55	65.00
Equipment	2,100.99	550.30	2,946.68	6,379.16
Buildings and land	—	—	15.00	3,657.36
Unexpended Balance	—	—	—	2.06
Total	$15,000.00	$15,000.00	$60,000.00	$126,285.33

*This fund includes the following:

State appropriations for Home Station	$63,133.83
For Grain Laboratory and Branch Stations	47,357.93
Income from sales	15,793.57

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